Efforts to Understand Discrepancies between Subcritical Measurements Analysis Techniques

J. Blair Briggs
Idaho National Laboratory (INL)

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Outline

1. Status ICSBEP Subcritical Benchmark Evaluations
2. A short history of the problem
4. Efforts to resolve the problem
5. Recommendations from various reviews
6. Summary

Status of ICSBEP Subcritical Evaluations

- Beta ratios
  - ZPPR-20
    - SUB-HEU-MET-FAST-001
    - SUB-HEU-MET-MIXED-001
- Modified Source Multiplication
  - Fuel Transport Flask
    - SUB-LEU-COMP-THERM-001
- CSDNA
  - Uranyl Nitrate Tanks
    - SUB-HEU-SOL-THERM-001
    - SUB-HEU-SOL-THERM-002
  - MURR Fuel
    - SUB-HEU-MET-THERM-001
    - SUB-HEU-MET-THERM-002
  - Poly-reflected Pu
    - SUB-PU-MET-FAST-001
- CSDNA / Feynman
  - Experiments performed at CEF/DAF but not completely evaluated
    - Acrylic-reflected Pu
    - Nickel-reflected Pu
    - Tungsten-reflected Pu

Short History of the Experiment Evaluation and the Problem Encountered

1. Subcritical measurements were performed on a nickel-reflected plutonium metal sphere
2. Two measurement techniques were used
   - ^{252}Cf Source-Driven Noise Analysis (CSDNA)
   - Feynman Variance-to-Mean
3. The Original ICSBEP evaluation was submitted in 2009
4. Early discrepancies between inferred k_{eff} values from the two methods exceeded 3 sigma(2 – 3%)
5. A revised ICSBEP evaluation was submitted in 2010, but the main CSDNA analysis tool, MCNP-DSP is no longer functional

Actions Taken to Resolve the Problem

- Original ICSBEP review comments addressed

- Formation of an International Group of Experts
  - John K Mattingly, Sandia National Laboratory
  - Dick McKnight, Argonne National Laboratory
  - Nicolas Authier, Commissariat À L'Energie Atomique (CEA)
  - Jim Gulliford, OECD Nuclear Energy Agency
  - George Imel, Idaho State University

- Robert Schaefer ICSBEP Working Group Review and subsequent discussions with Tim Valentine

Major Issues Raised During Original ICSBEP Review

- Source and detectors were configured asymmetrically in an effort to balance the detector readings for CSDNA measurements
- Different detector configurations were used for the two measurement methods
- Questions regarding detector efficiency lead to additional transmission measurements and adjustments to transmission ratios for the Feynman measurements
- Inferred k_{eff} values from Feynman Variance-to-Mean measurements were increased and the discrepancies were reduced to about 1%

Recommendations by the International Group of Experts

- Recommendations by the International Group of Experts focused on the Feynman measurements and analysis
- Point kinetics approximation is not entirely valid — A correction factor needs to be derived and applied
- Fission nubar data should be used instead of delayed nubar data
- Discrepancy reduced to approximately 0.2%

Recommendations by Robert Schaefer and / or Tim Valentine

- Recommendations focus only on CSDNA measurements and analysis
- Uncertainty in the CSDNA due to asymmetrical positioning of the source must be addressed either by experimentation or calculation
- A correction to account for the efficiency of the source-detector in counting the ^{252}Cf spontaneous fission needs to be determined

Recommendations by Robert Schaefer and Tim Valentine (Continued)

- A new Californium source should be fabricated and a pulse height curve developed to set the discrimination between alpha decays and spontaneous fission decays
- The subcritical measurements of the nickel reflected plutonium metal sphere should be repeated using the same detector system for both measurement methods with a symmetrical source-detector configuration

Recommendations by Robert Schaefer and Tim Valentine (Continued)

- A functioning and validated code to calculate spectral ratios must be developed.
- When the code becomes available, the stability of spectral ratios as a function of Cf/Pu source ratio should be studied.
- The new generation of experimentalists should use the code, as well as experimental studies, to gain a feeling for what is, and is not, important in this experimental technique.
- Measured and calculated output data should be carefully scrutinized and tested for consistency and validity.

Recommendations by Robert Schaefer and Tim Valentine (Continued)

- Uncertainties and biases should be evaluated for not just k_{eff} but also the spectral ratios
- SUB-PU-MET-FAST-003 analysis should be repeated using the new experimental results and newly developed analytical tools
- Only after all the above recommendations are successfully completed, would it be worthwhile to do new CSDNA experiments
- New experiments should always include built-in checks, such as symmetrically placed detectors, to monitor whether valid results are being produced

Summary

- Errors were inadvertently made in both the measurement and analysis of the nickel-reflected plutonium metal sphere experiments that resulted in large discrepancies in the inferred k_{eff} values obtained from the CSDNA and Feynman methods
- Tools to analyze CSDNA measurements were not under configuration control and were lost due to operating system upgrades at ORNL, but new analytical tools are under development.
- The subcritical measurements of the nickel-reflected plutonium metal sphere should be repeated using the same detector system for both measurement methods
- The SUB-PU-MET-FAST-003 evaluation should be repeated using the newly measured data and newly developed analytical tools